Operational Applications of Satellite Altimetry

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Introduction

Since 1996, the Colorado Center for Astrodynamics Research (CCAR) has hosted near real-time maps of mesoscale SSH anomalies on the web to encourage operational use of satellite altimetry.

In this presentation, I will highlight several example applications and data syntheses using satellite altimetry including:

- offshore operational support in the Gulf of Mexico,
- oceanographic survey design,
- marine mammal and sea turtle migration patterns related to oceanographic circulation,
- and oceanographic consulting.

Offshore Operational Support: Gulf of Mexico

Data User: Capt. Karl Greig, captain of a large anchor handling tug boat owned by Edison Chouest Offshore.

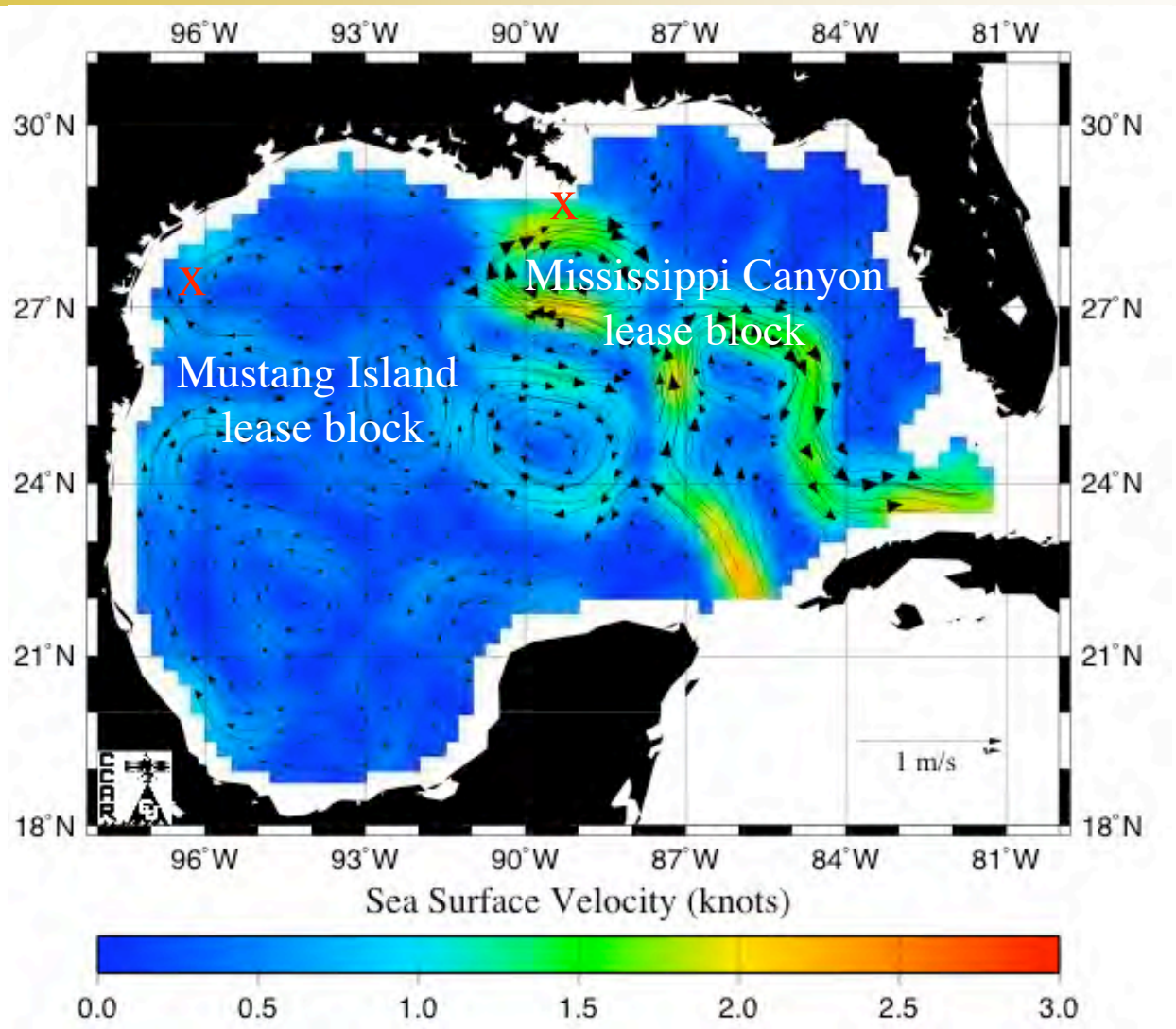
Application: Route finding for towing semi-submersible drilling rigs used in deepwater oil and gas exploration.

Operation: Moving a rig from Mississippi Canyon block 68 to Mustang Island block 68, a total of 425 nautical miles. Typical towing speeds are 3 to 4 knots so avoiding and/or using eddy currents significantly reduces transit times, in this case by over 50 hours.

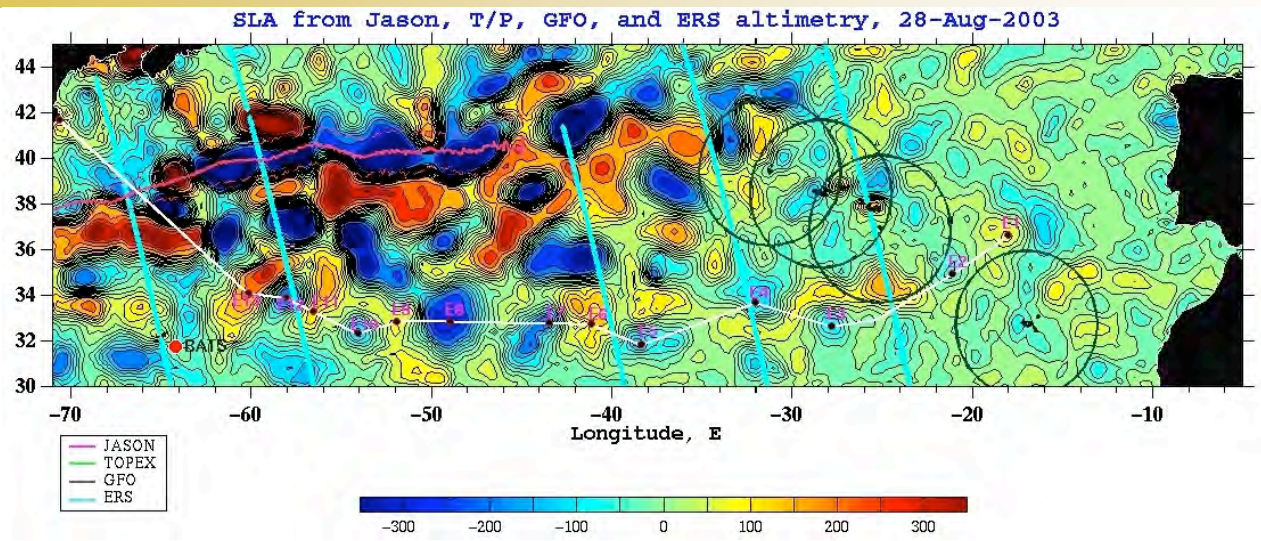
Altimeter Product Used: Overlays of geostrophic velocity vectors on colored magnitudes values accessed on CCAR website by satellite phone.

Estimated Savings: $650,000 in rig downtime and towing costs.

Near real-time currents: August 15, 2003

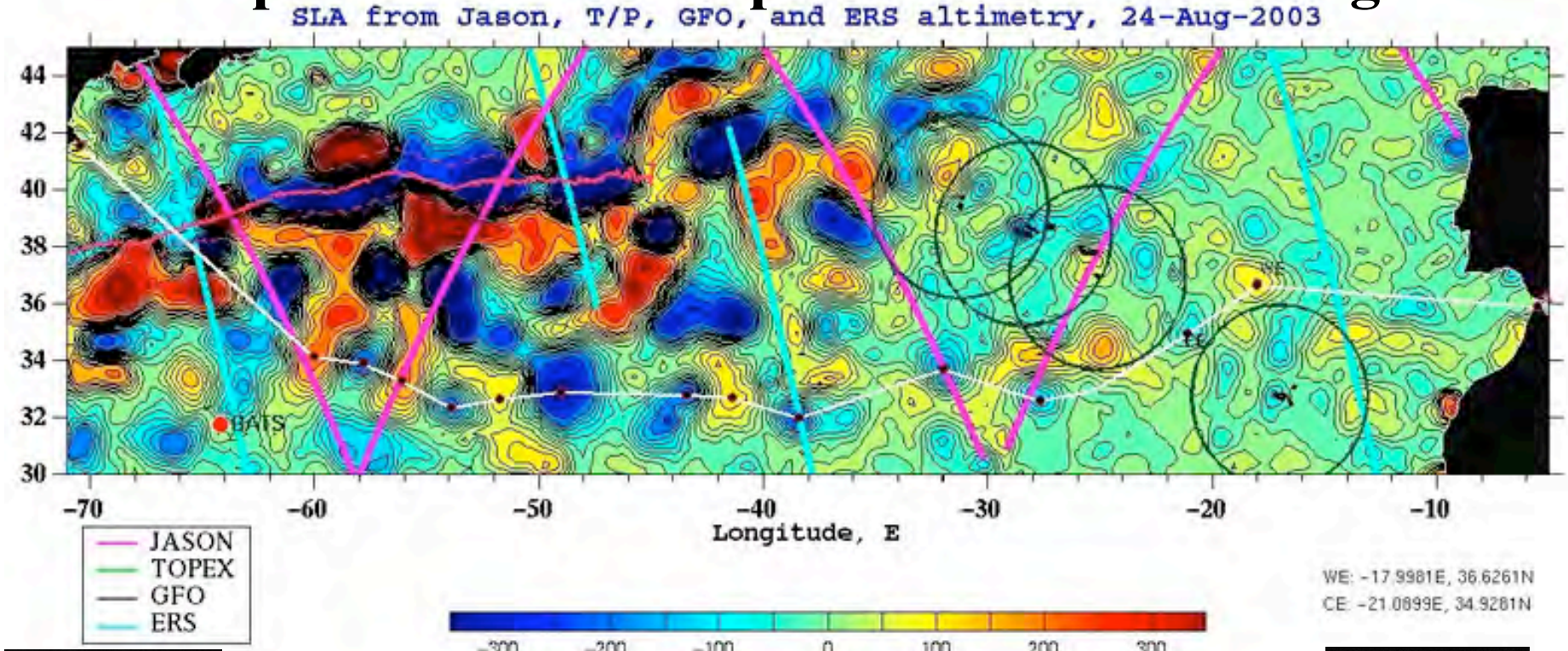


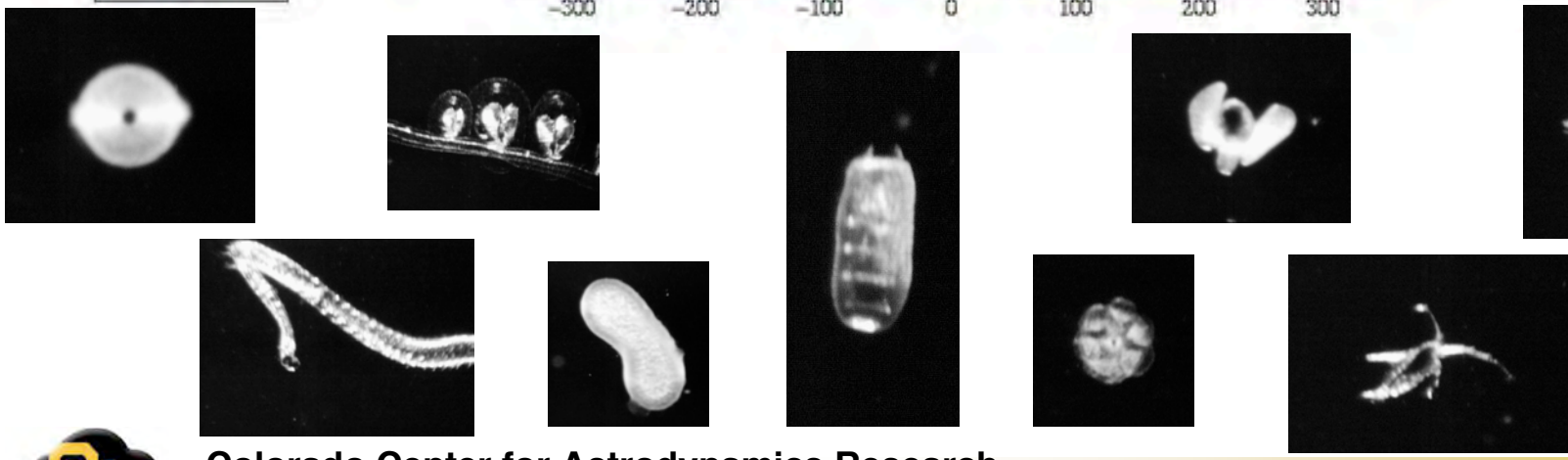
Survey Design: *R/V Knorr* Transatlantic VPR survey



Data User: Dennis McGillicuddy and Valery Kosnyrev, WHOI
Application: Support of transatlantic research expedition from Malta to Woods Hole on the *R/V Knorr*, Chief Scientist Dr. Cabell Davis
Operation: Identify eddy features to sample with the Video Plankton Recorder, a video microscope mounted on an vehicle towed behind the ship.
Altimeter Product Used: Near-real time along-track data, which were used by the investigators in to map SSHA and select way points.

Sample altimeter data product and VPR images





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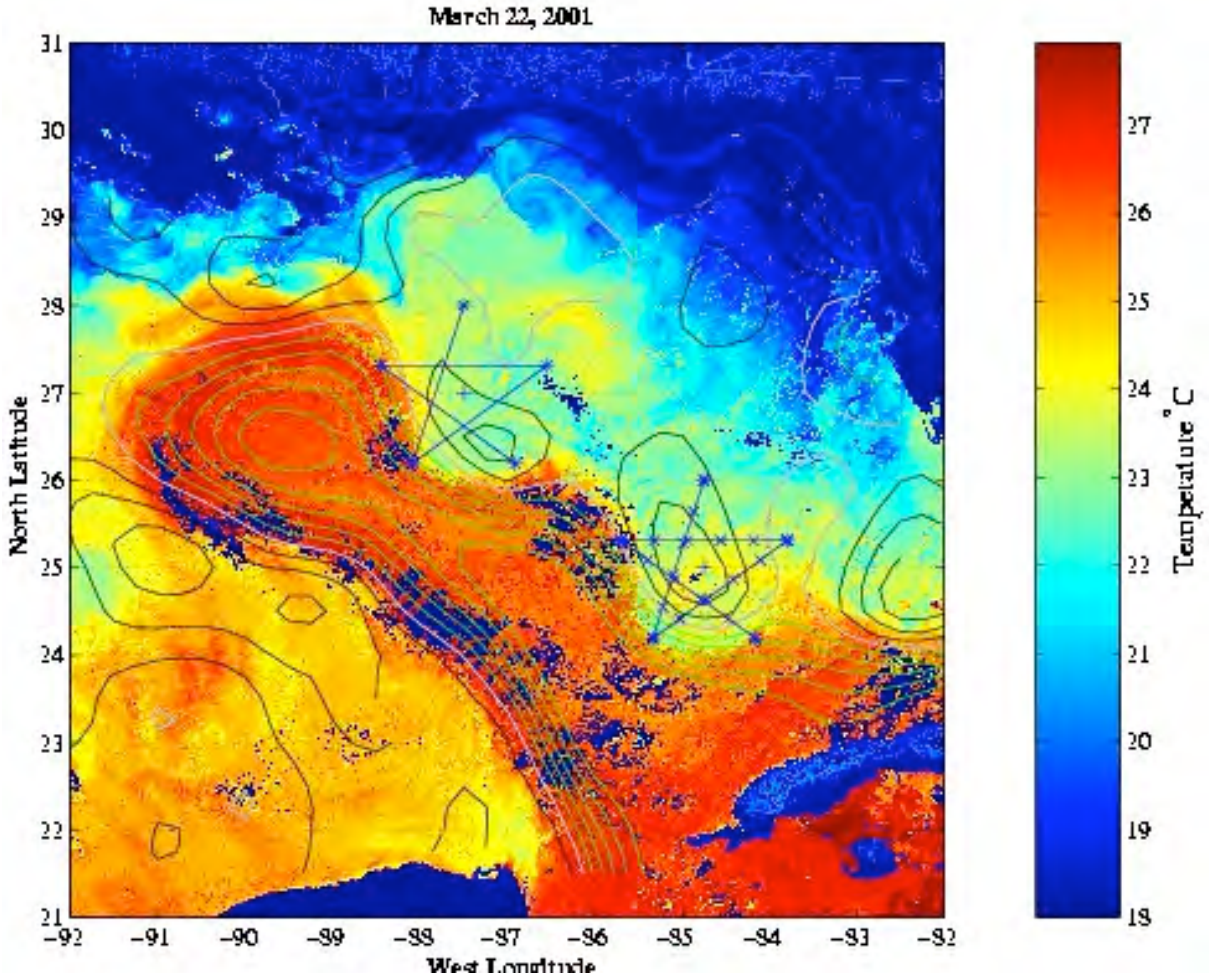
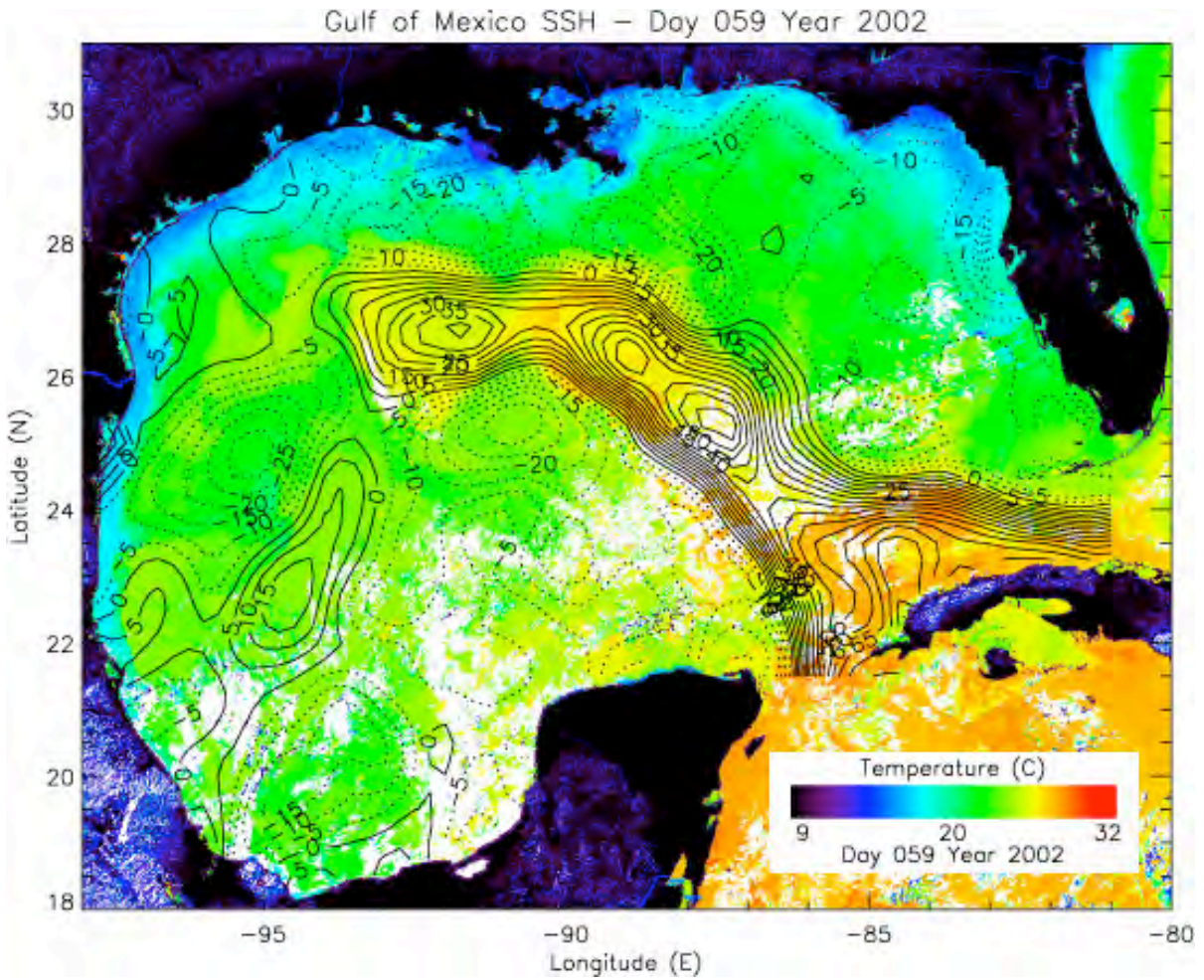
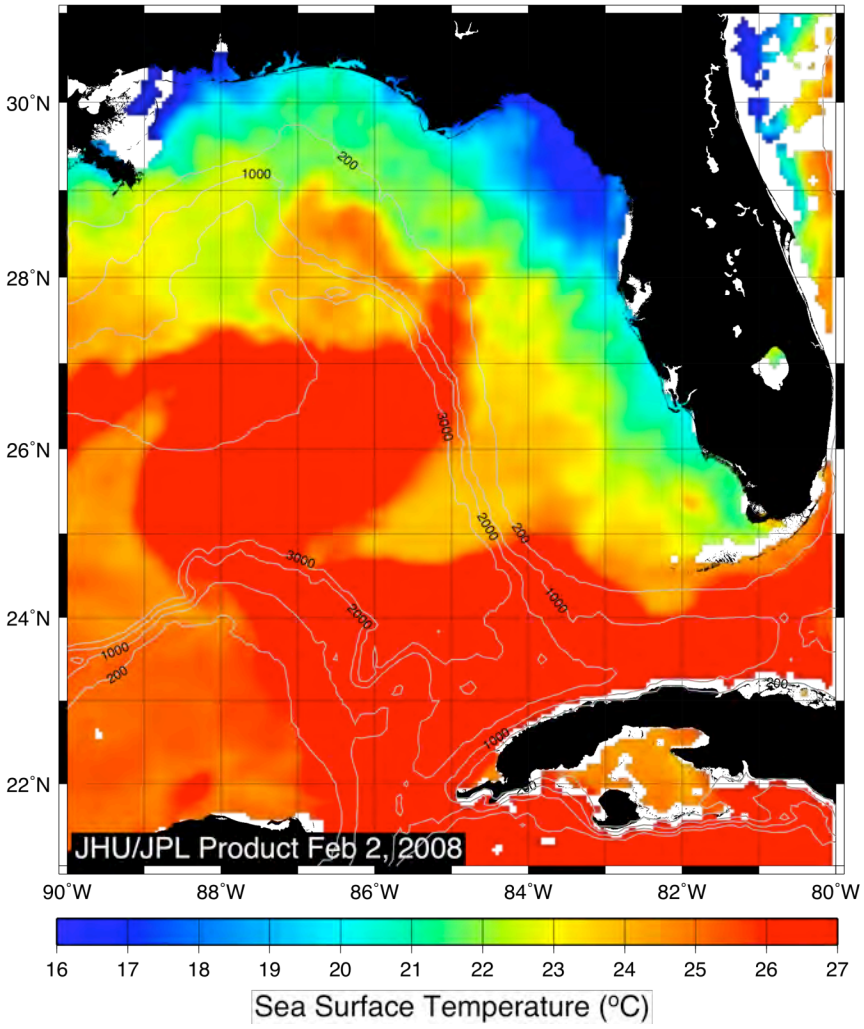
Survey Design for Whale Survey MMS/NMFS

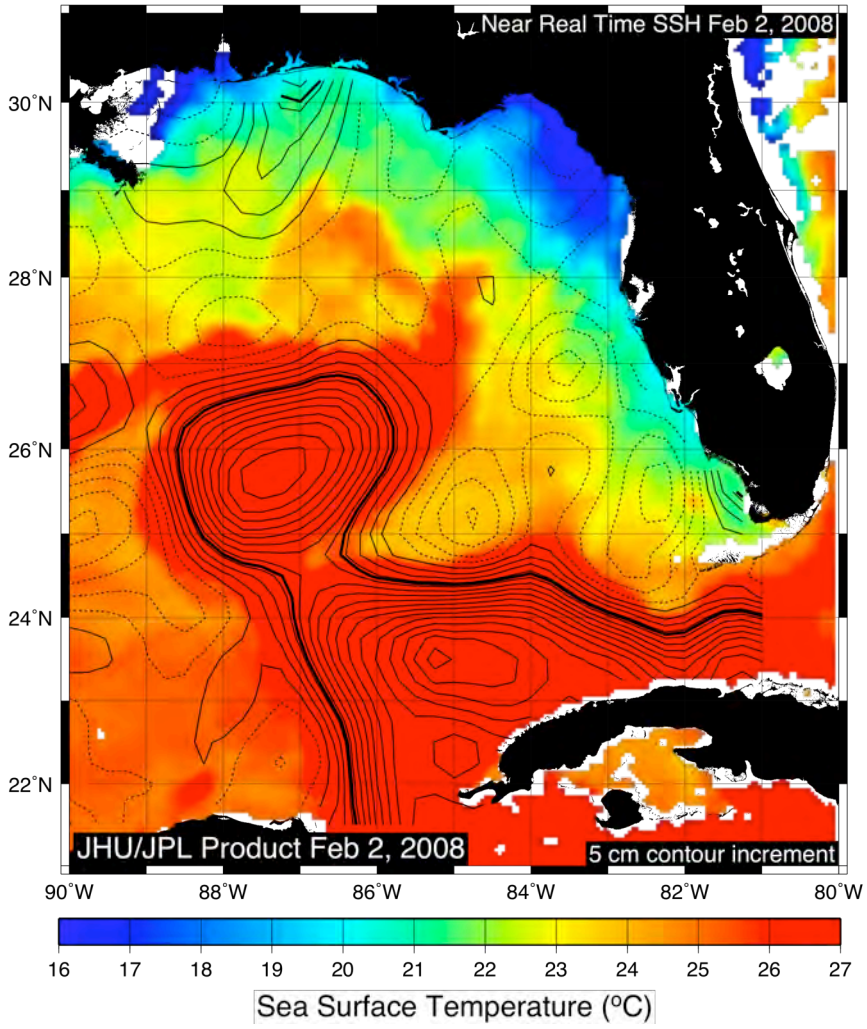


Online SSH/SST Overlay

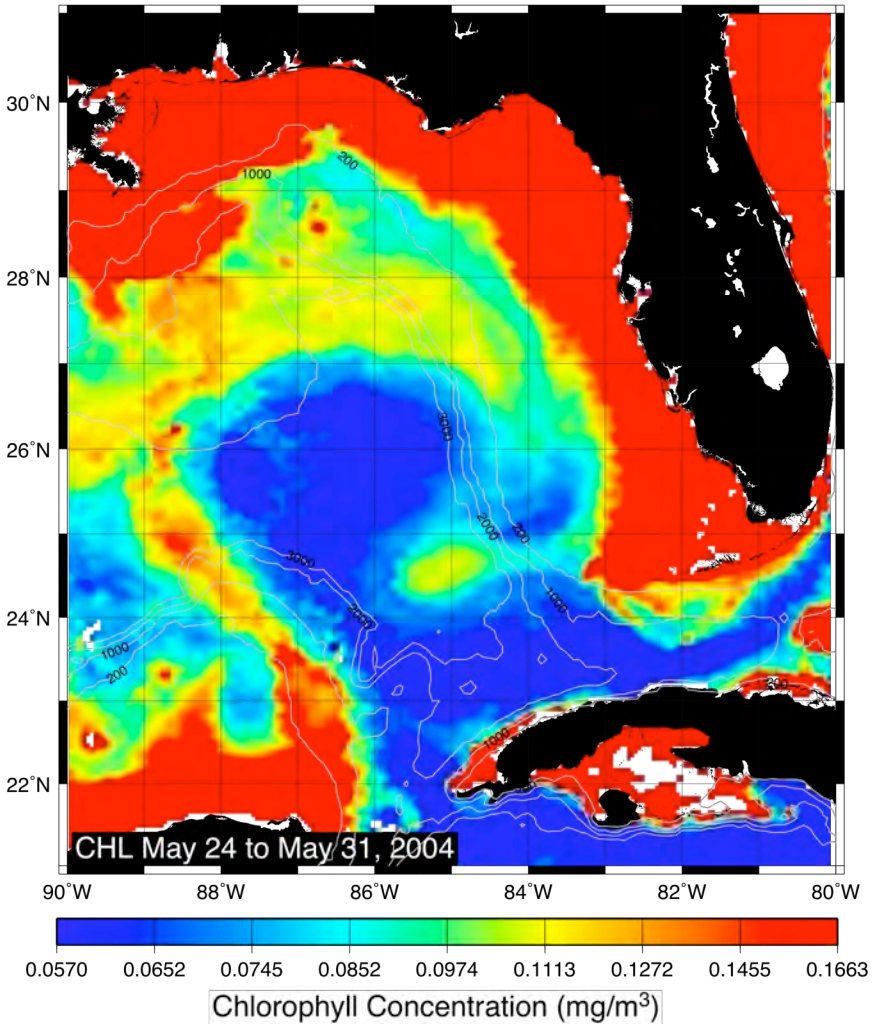


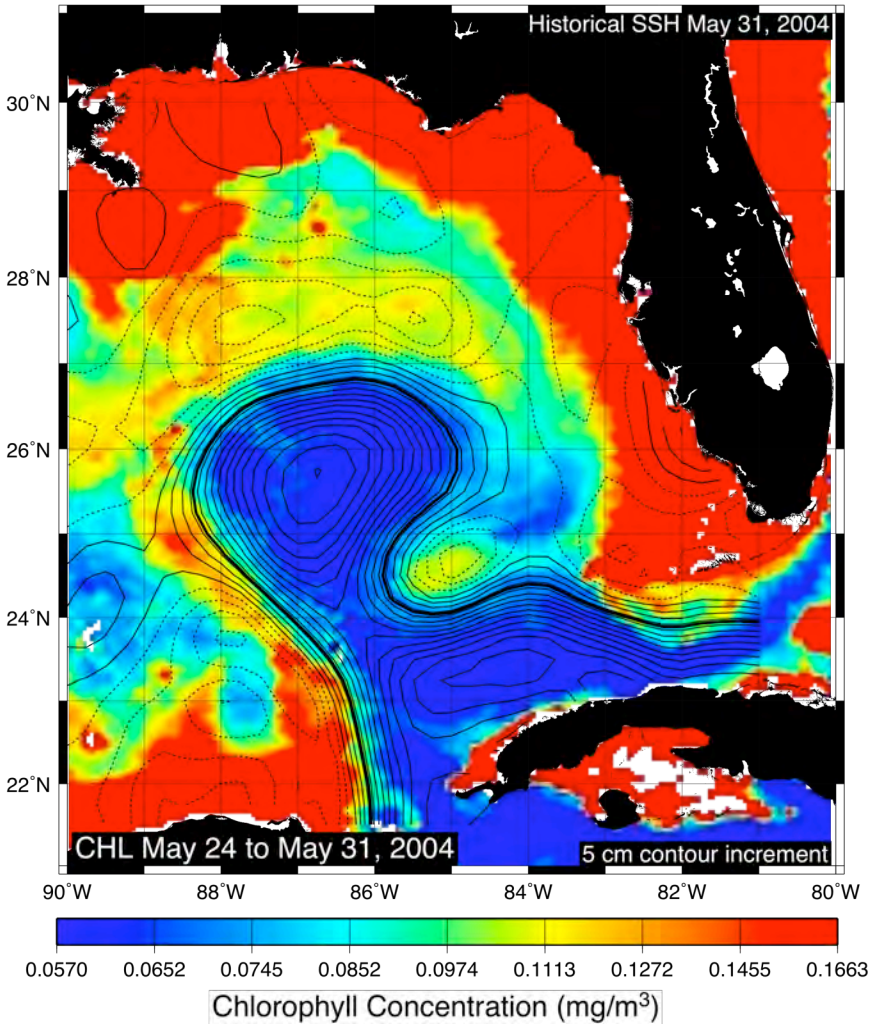
SST with and without SSH Overlaid





Ocean Color with and without SSH Overlaid





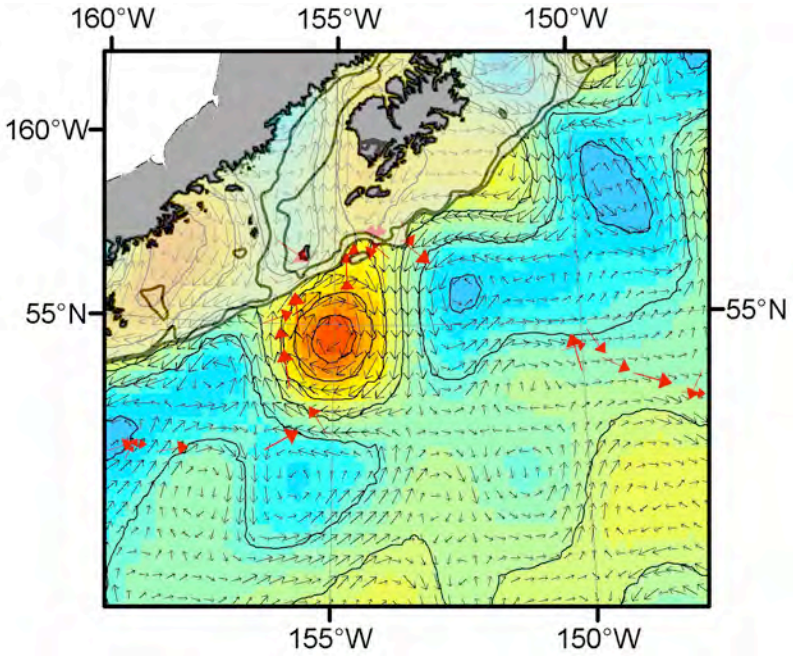
Northern Fur Seal Wintertime Migration Patterns

Data User: Jeremy Sterling, fisheries biologist at the NOAA National Marine Fisheries Laboratory.

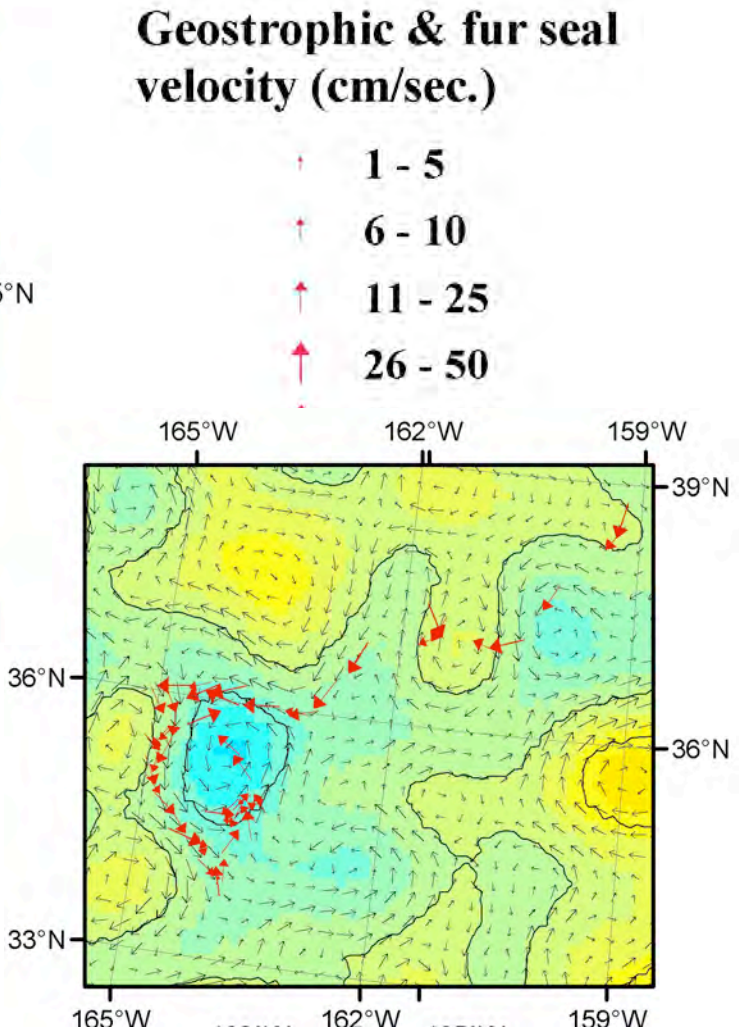
Application: Relating satellite-track position and velocity data of northern fur seals during wintertime migration in the North Pacific to observed oceanographic conditions.

Altimeter Product Used: Near-real time and historical mesoscale SSH anomaly data.

Satellite tracked northern fur seals

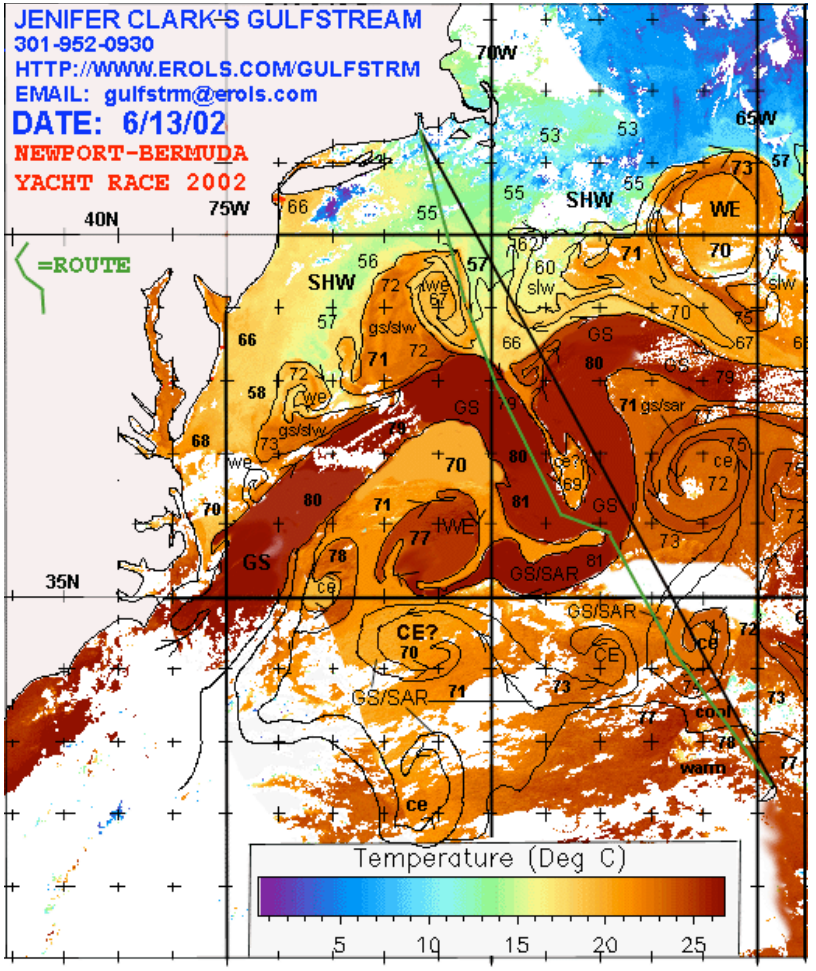


Fur seals linger near mesoscale eddy features in North Pacific during wintertime migration.



Jenifer Clark's Gulf Stream

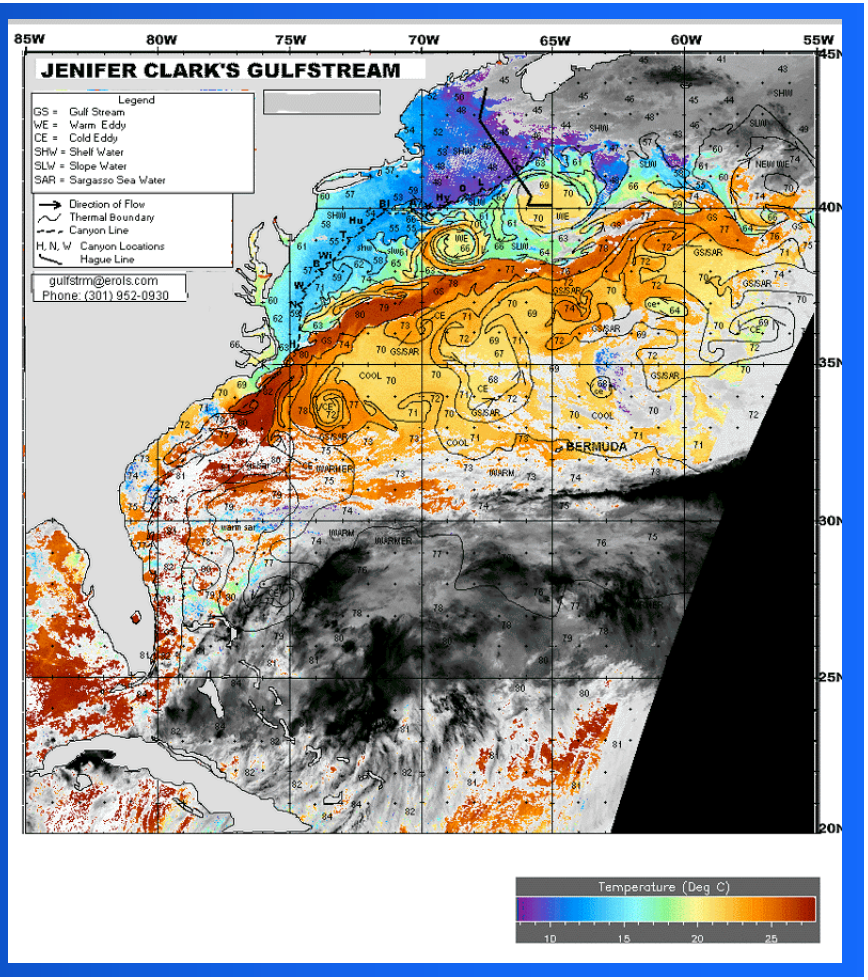
Data User: Jenifer Clark, professional satellite oceanographer.
Application: General marine consulting.
Operation: Using near real-time altimeter data with sea surface temperature imagery to evaluate currents affecting offshore operations.
Altimeter Product Used: Near-real time data SSH and geostrophic velocity data viewers.



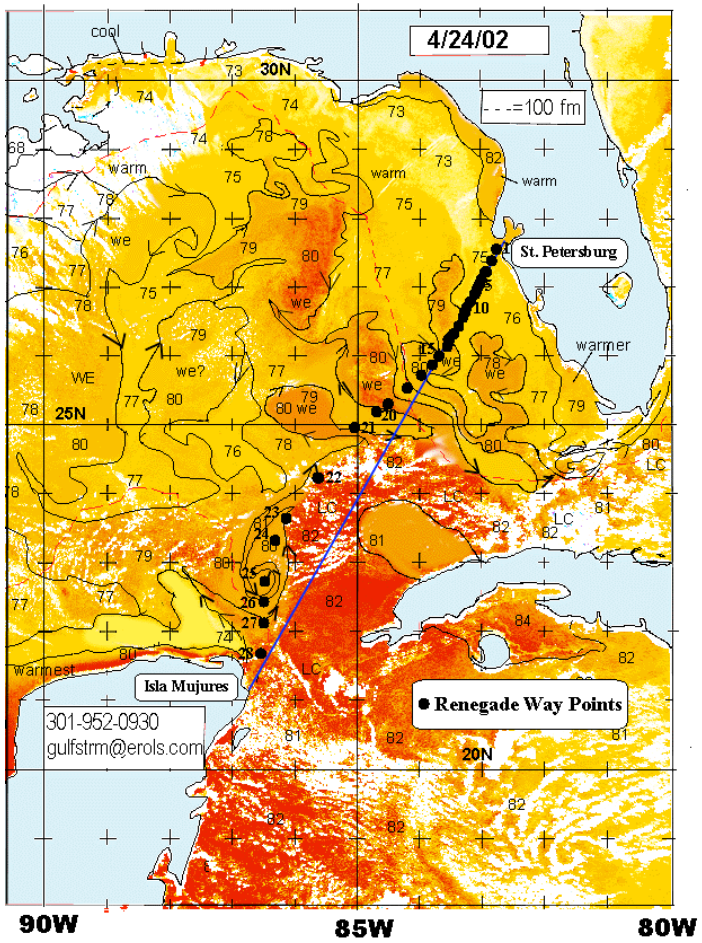
Jenifer Clark's Gulf Stream

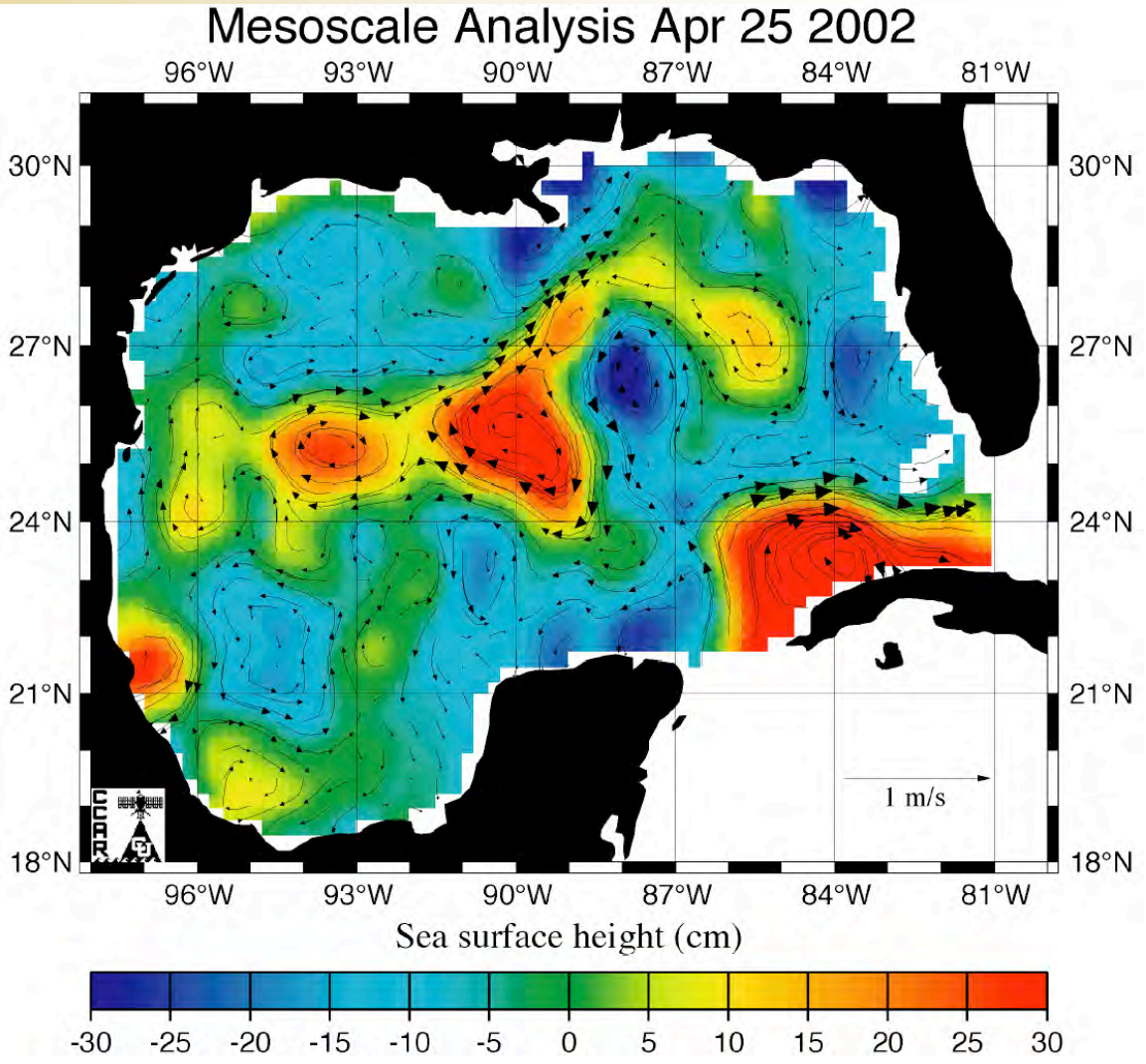
http://users.erols.com/gulfstrm/

- Sailboat Races
- Ocean Routing
- Sea Surface Temperatures
- Fishing Charts
- Marine Consultation
- Boat Deliveries
- Current Analysis



Sport Sailing





Deep Sea Recovery

Design and Decision Support Tool: Gulf of Mexico

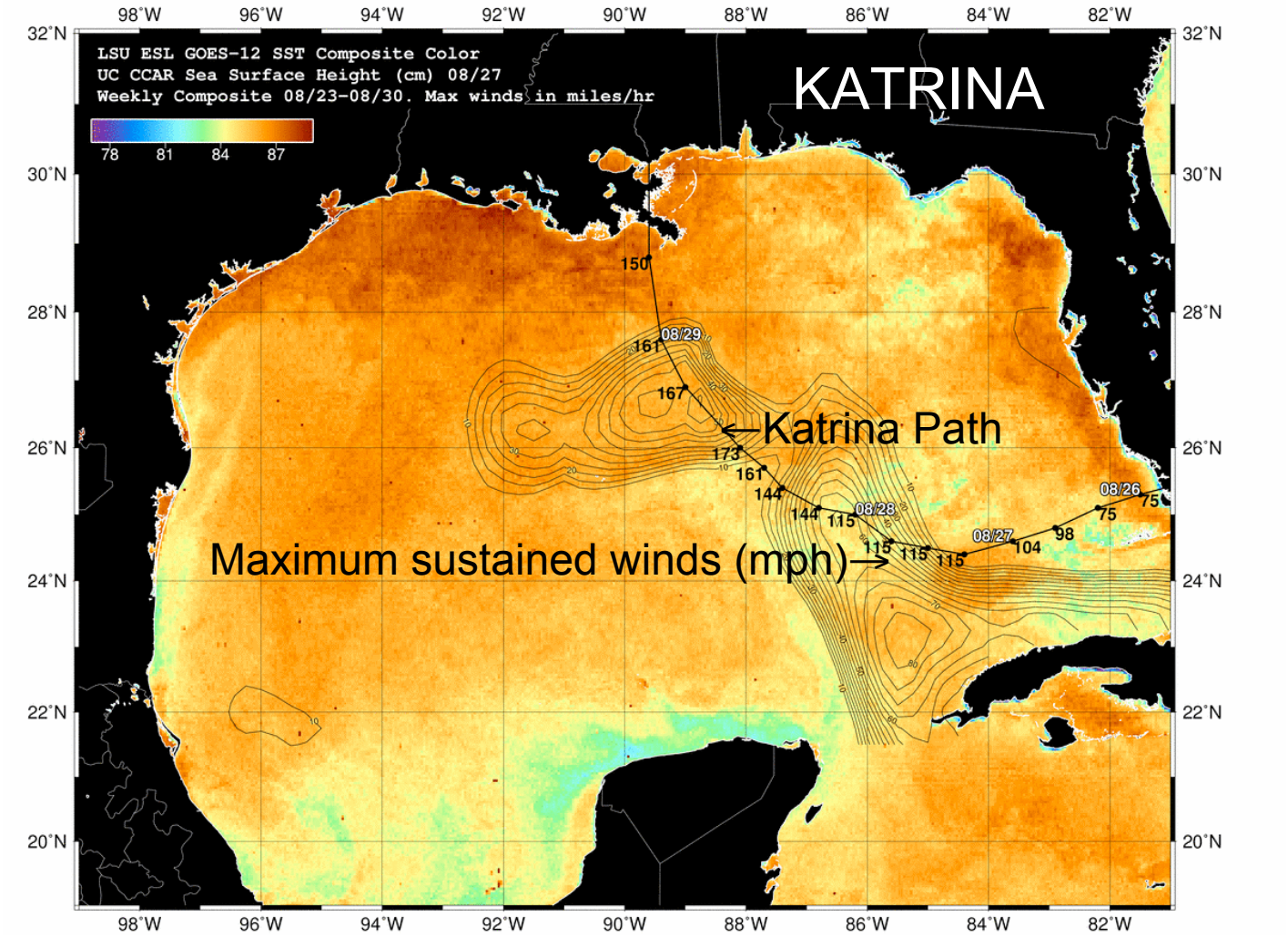
Data User: "Climatology and Simulation of Eddies" Eddy Joint Industry Project (CASE/EJIP)

Application: Develop a synthetic time series of Loop Current and associated eddies to use as input to a hurricane model to derive 50- to 1000-year design criteria for extreme hurricane/Loop Current events.

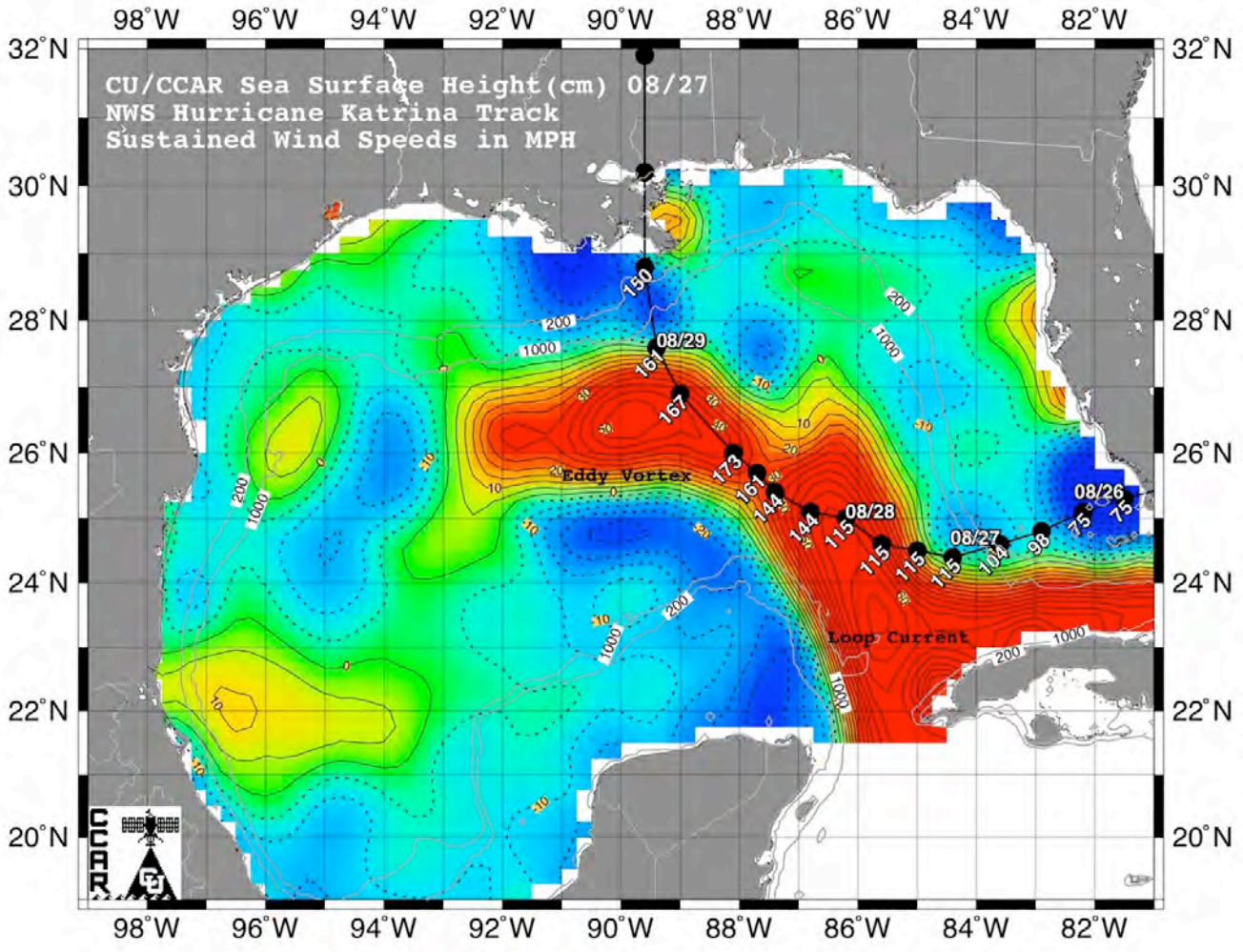
Operation: Design and decision support for offshore exploration and production activities.

Altimeter Product Used: Altimeter-derived Loop Current and Loop Current eddy positions and statistics.

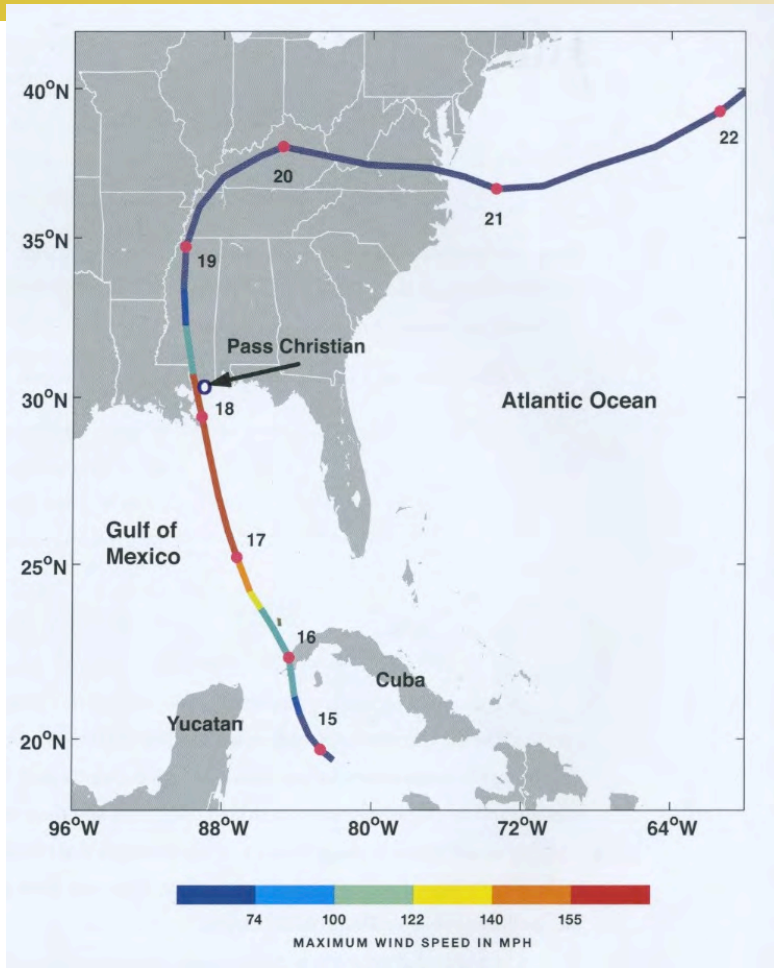
Why is the Loop Current important?



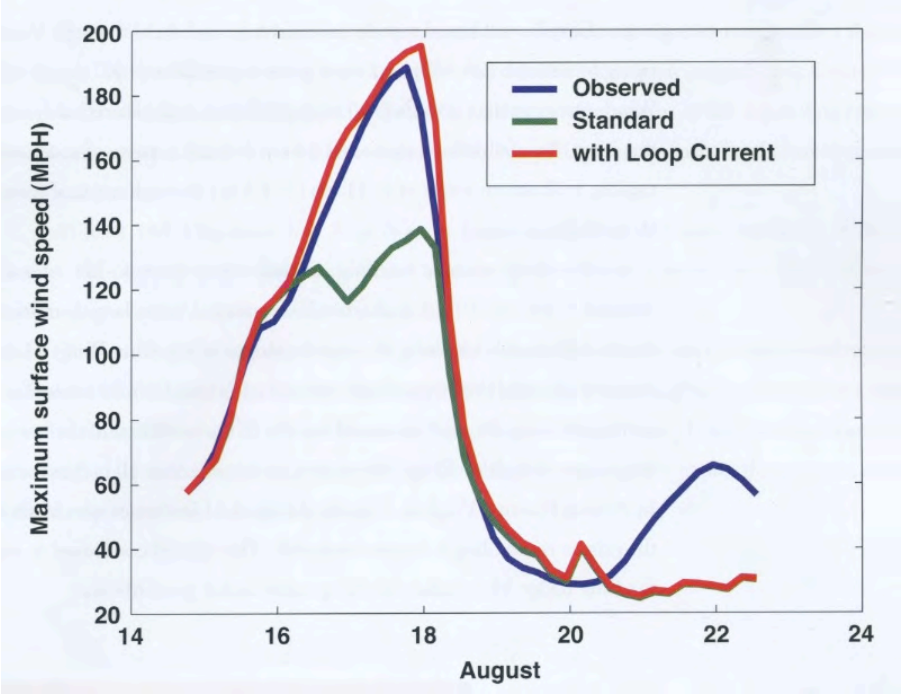
CCAR SSH Map Overlaid with Katrina Path/Sustained Winds



1969 Hurricane Camille



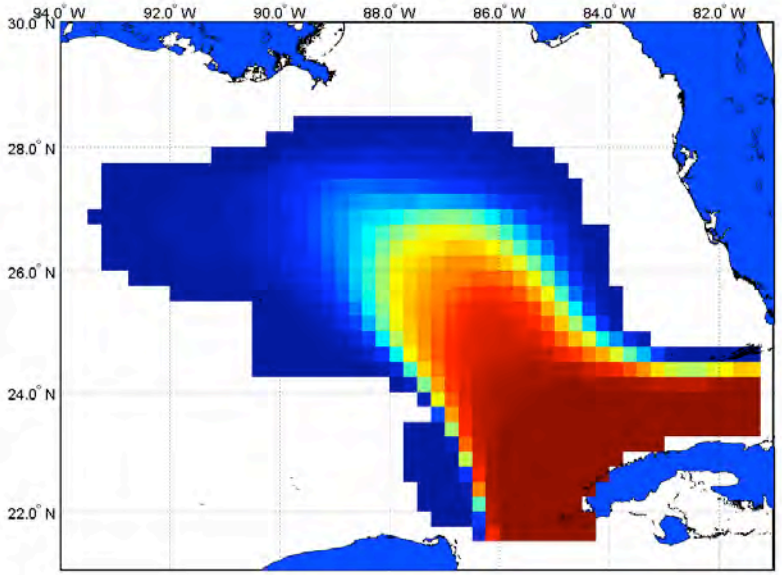
- Category 5 at landfall near Pass Christian on August 18, 1969.
- Hindcast 1-D modeling studies implicates Loop Current in the rapid intensification and severe strength.



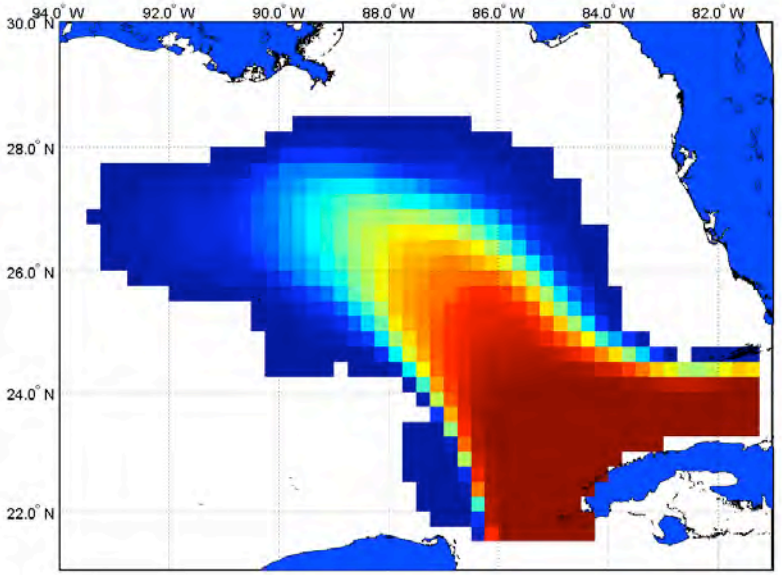
From *Divine Wind: The History and Science of Hurricanes by* Kerry Emmanuel

Simulation

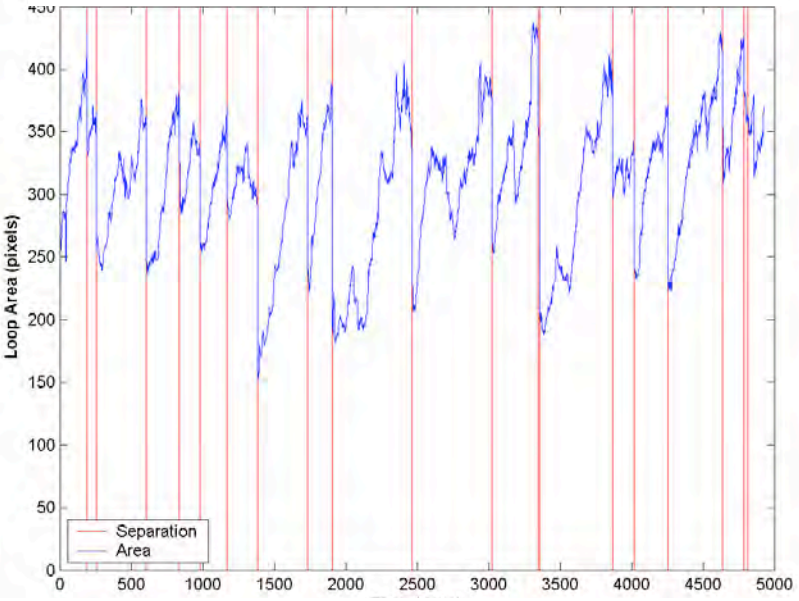
Altimeter Mean LC Coverage



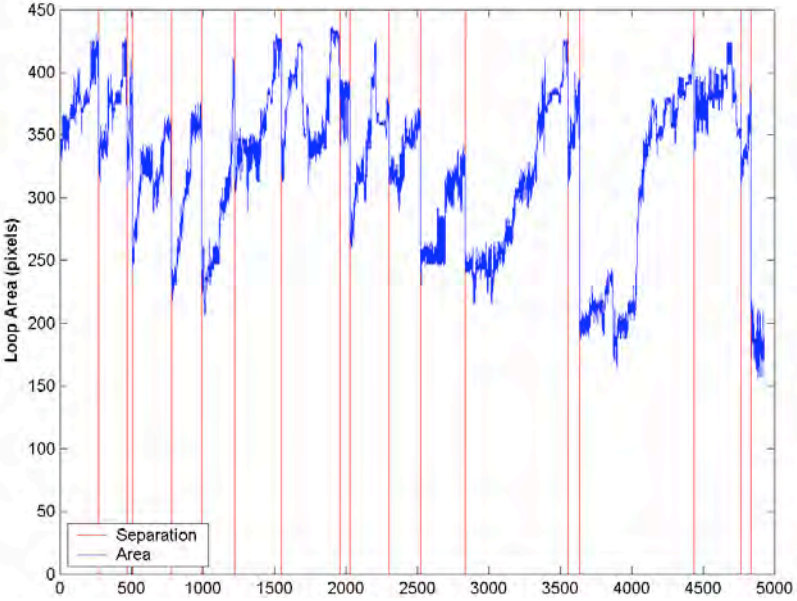
Simulated Mean LC Coverage



Altimeter Loop Area



Simulated Loop Area



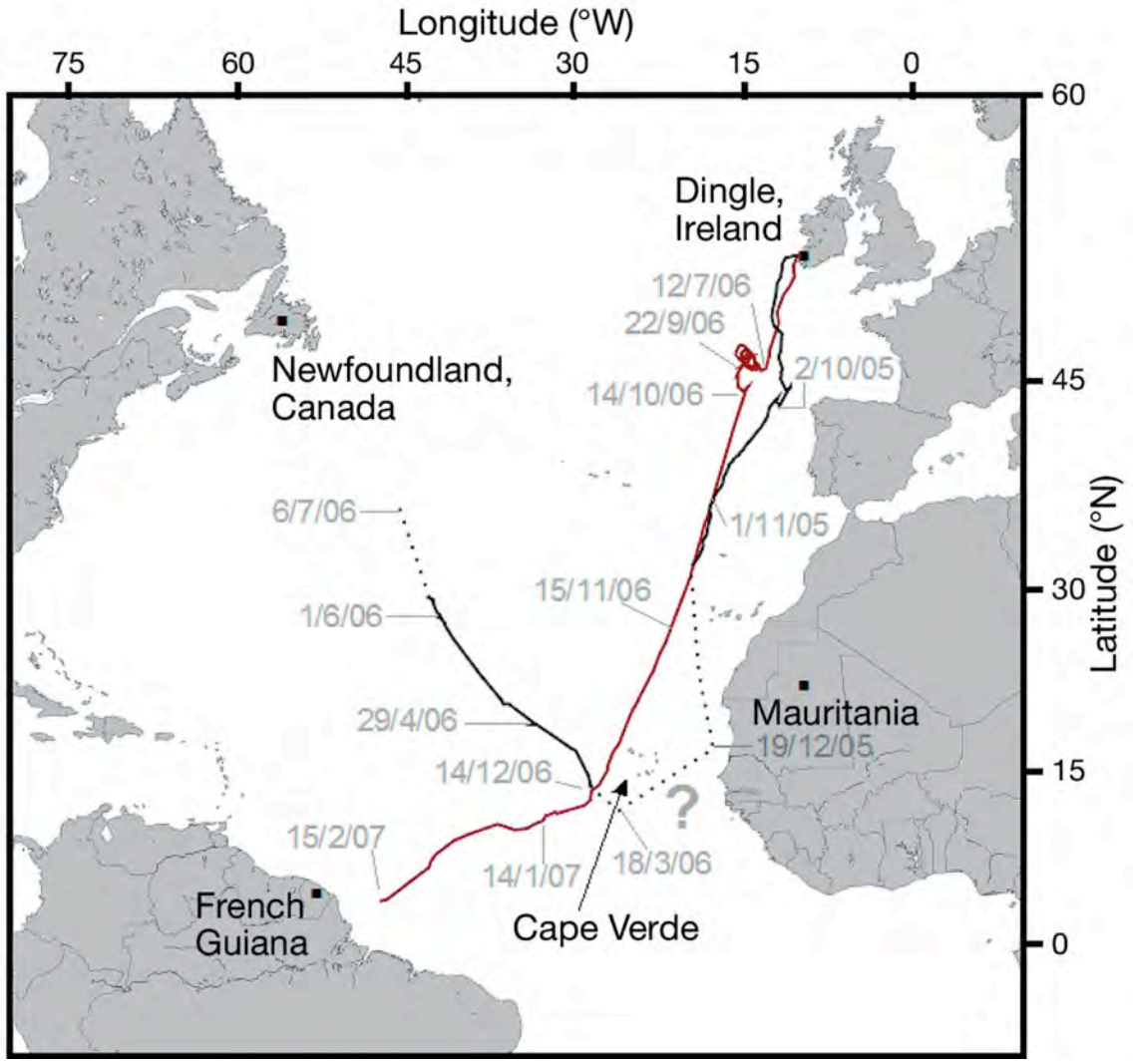
Satellite-tracked Leatherback Turtles

Data User: Dr. Tom Doyle of the Irish Sea Leatherback Turtle Project http://www.turtle.ie/ is using satellite altimetry to improve understanding of leatherback turtles in the Irish Sea.

Application:. Uses sea surface height maps to interpret turtle movement and migration patterns in relation to ocean mesoscale eddy field.

Altimeter Product Used: Near-real time and historical mesoscale sea surface height anomaly fields.

Leatherback Turtle Tracking



Jellyfish thriving in our coastal seas

• Sunfish in Tralee Bay. Photo by Ronnie Fitzgibbon.

• Blue jellyfish. Photo by Matthew Slightam.

• Portugeese man of war. Photo by Rowan Byrne.

• Common Jellyfish. Photo by Sarah Varian.

OUCH! How many of us have felt the pain of a jellyfish sting? We see them washed up on our beaches and most of us avoid them with a shudder. But have you ever stopped to look at them? Have you ever wondered what are they made of? What is their function in the seas that surround the island of Ireland?

Jellyfish are some of the most abundant and noticeable members of our coastal marine fauna. Individuals can grow to one metre in diameter and weigh as much as 200kg. Jellyfish blooms (or swarms) can extend for kilometres and contain millions of individuals. Even though we see these creatures all the time, we have only a basic understanding or appreciation of their diversity, ecology and life history.

Until very recently, jellyfish have been neglected by researchers worldwide. This is largely to do with the difficulty in studying these delicate and often transparent animals. Novel techniques such as beach surveys, and pioneering new technologies (deep-sea submersibles, scuba diving and even observing jellyfish from aircraft) however, are beginning to provide a new appreciation of their diversity. Once considered unimportant, jellyfish are now known to play a large role in the dynamics and functioning of coastal marine environments.

What are jellyfish?

JELLYFISH belong to a group of animals called Cnidarians (pronounced nigh-dare-ree-annes), which also includes sea anemones and corals. They have a very simple body plan (e.g. no heart, bones, liver, brain, or lungs); they don't have a left and right side, and have 'stinging cells' that they use for food capture and protection.

Composition

They are composed almost entirely of water (up to 96%) and use the muscles of their body wall to push against this fluid inside, to create a pulsating swimming movement. The adult jellyfish or the medusa is typically bell or domed shaped, very large, short-lived (months rather than years), and swims.

Jellyfish however, are present throughout the year in another form — the polyp.

Shape

The polyp is shaped like a minuscule vase (a few millimetres in height) with tiny tentacles attached around the rim. It looks something like a tiny sea anemone and normally attaches onto rocky substrates or shells in shallows coastal environments, and can live for many years. Importantly, the polyp produces the adult jellyfish. **(see life cycle figure)**

Irish varieties

IRELAND has five indigenous jellyfish species: Barrel; Blue; Common (Moon); Compass and Lion's Mane. A sixth species (Pelagia noctiluca) also occurs but is an oceanic species that is carried here by currents.

Contrary to common belief, jellyfish are not carried at the whim of ocean currents and tides onto our beaches. Many jellyfish maintain their positions by swimming down when the tide is going out, and swimming up when the tide is coming in. In this way they can stay in their preferred habitats.

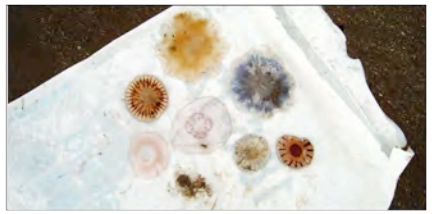
For example, the Barrel jellyfish forms enormous blooms every year off Rosslare and Wexford Harbours, yet is rarely found elsewhere in such numbers. The Lion's Mane jellyfish prefers the cooler waters of the Irish Sea and especially the waters off Dublin. Even the Common jellyfish, which is the most widespread species, seems to have a preferred habitat. It is most often located in harbours and estuaries and at times can form the densest blooms.

The Blue jellyfish and in particular the Compass jellyfish, are found in highest numbers off the south and west coasts, and at times can be found throughout the entire Celtic Sea.

• Juvenile fish have been observed to find shelter under the bells of jellyfish. This one is a Compass Jellyfish

Photo by John Collins

• The leatherback sea turtle swims all the way from the Caribbean and west coast of Africa to feed on Ireland's abundant supply of jellyfish. Photo by Ian Slevin.



• Jellyfish diversity and variations within species. From bottom left in clockwise order: aequorea (not a true jellyfish but looks like one), compass, blue, blue, compass, blue, and common jellyfish. Photo by Tom Doyle.

Are jellyfish increasing globally?

THERE is growing concern that jellyfish are becoming more abundant in our coastal seas. In the Bering Sea off Alaska, scientists documented a ten-fold increase in jellyfish abundance during the 1990s. Other examples include the Gulf of Mexico and the Sea of Japan.

Nevertheless, very few long-term datasets exist to help determine why jellyfish populations are on the increase.

In some areas, extensive over-fishing has removed many of the top predators (e.g. large fish species) thus leaving a 'niche' for jellyfish to fill. In other areas, recent shifts in climate may have driven these unprecedented increases in jellyfish abundance. In Irish waters it is impossible to say whether we have experienced any increase in jellyfish. The closure of beaches in Dublin in 2005 because of the Lion's Mane jellyfish, may suggest that this is true. At present however, there is insufficient data to support this view.

'Jellyfish as food'?

Living on a diet of jellyfish may not seem like a clever thing to do as they have few nutrients and are full of venom! Yet many marine animals feed entirely on jellyfish. The leatherback sea turtle swims all the way from the Caribbean and west coast of Africa to feed on Ireland's abundant supply of jellyfish! It is not entirely clear how such large animals (they are the size of a cow) can survive on a diet of jellyfish?

One thing is for sure; they have to eat an awful lot of jellyfish, maybe as much as 100kg daily! Another animal that feasts on jellyfish is the ocean sunfish. Sunfish have a really weird shape and are sometimes called swimming heads. Every summer they can be observed in our coastal waters feeding on jellyfish. **See photo.**

Floats like a butterfly, stings like a bee

ALL jellyfish have stinging cells that they use for protection and to stun and capture their food. These stinging cells are unique in the animal kingdom and only jellyfish and their close relatives (corals and sea anemones) possess them.

The stinging cell is probably the most complicated single cell found in any animal, although very few of us appreciate this marvel of evolution when stung!

A stinging cell is like a tiny balloon with a miniature harpoon coiled up inside it. When the balloon bursts upon contact with an object, the harpoon is fired and injects venom into an unsuspecting animal (or person). Luckily for us, our skin forms quite an effective barrier against most of these 'harpoon' attacks.

For example, the stinging cells of the Common jellyfish rarely break our skin and so have no effect. All stinging cells however, are strong enough to sting the more delicate tissues of our body such as eyes and lips. Some jellyfish, most notably the Lion's Mane, possess stinging cells that are much sharper and have no problem piercing our tough skin.

Jellyfish and fisheries

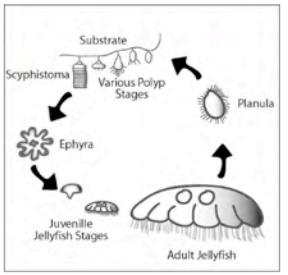
As highly efficient predators, jellyfish blooms can consume large quantities of fish eggs and larvae to such an extent that they may influence the number of fish available for capture. Furthermore, because jellyfish feed on fish food (i.e. plankton) they are also in direct competition with fish for the same resources.

On the other hand, jellyfish may also be beneficial to fish and the fishing industry.

For example, juvenile fish have been observed to find shelter under the bells of jellyfish **(see main photo).** Indeed, if you imagine a bloom of jellyfish with approximately 10,000 individual jellyfish, each with 20 juvenile fish underneath, then you could have approximately 200,000 juvenile fish finding shelter under this floating jelly habitat!

So at certain times, jellyfish blooms actually provide an important habitat for juvenile fish in a vast ocean.

• Common Jellyfish bloom. Photo by Michelle Cronin.



• Lifecycle of a jellyfish. Surce: vincenthyland.com

Lifecycle of jellyfish

DURING the height of the summer, adult jellyfish produce gametes (sperm and eggs), which are released into the water column where they fuse to form larvae.

After a few days of swimming, the larvae settle on rocky substrates and shells and then transform into polyps.

The polyps undergo a remarkable transformation during winter and early spring. They begin to horizontally divide, i.e. they clone themselves! This is a pretty unique way of turning one animal into many. Each clone (ephyra) is released from the polyp and begins to pulsate immediately like a jellyfish. After many months of feeding and growing, this juvenile jellyfish will develop into a fully-grown adult.

Where to find jellyfish?

ONE of the best places to see jellyfish is at your local beach.

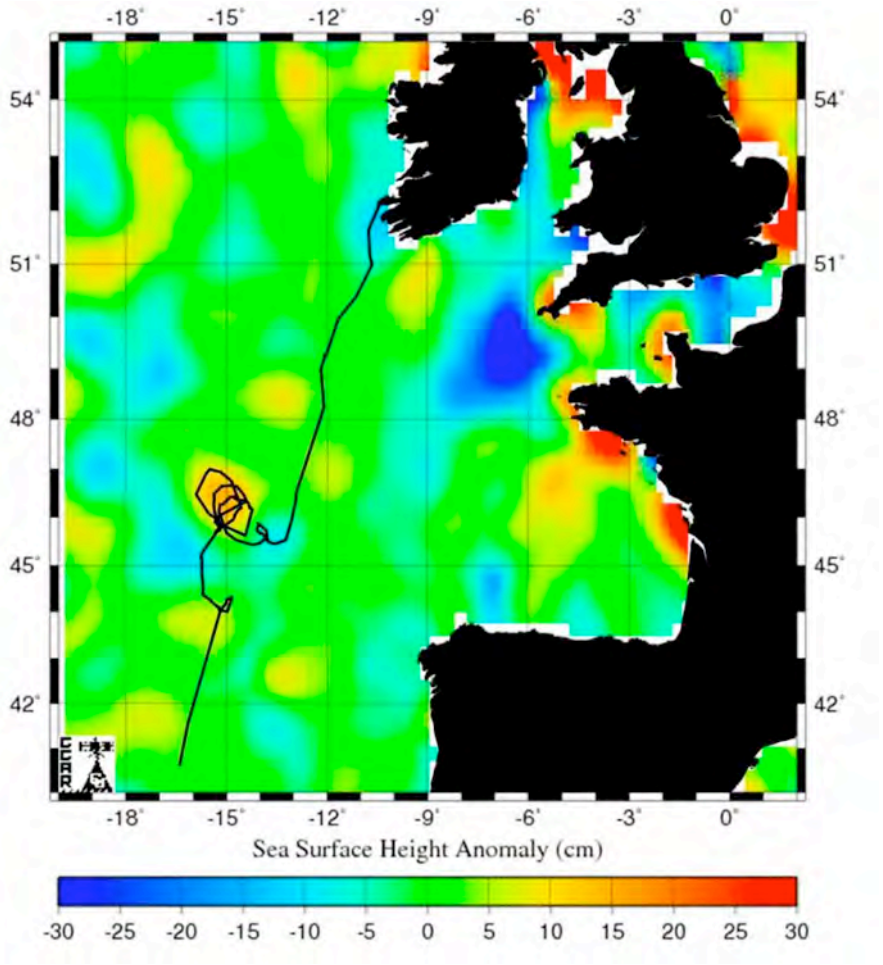
The photo on top left illustrates the diversity of jellyfish and the variation within the same species on an Irish beach. To learn more about jellyfish and to help scientists to carry out their research visit the website www.turtle.ie.

Turtle track overlaid on mesoscale SSHA

The large male turtle remained within an anticyclonic eddy for 66 days west of the Bay of Biscane in late summer 2006.

A marked change in dive behavior occurred as the turtle fed, presumably on jellyfish, within the eddy.

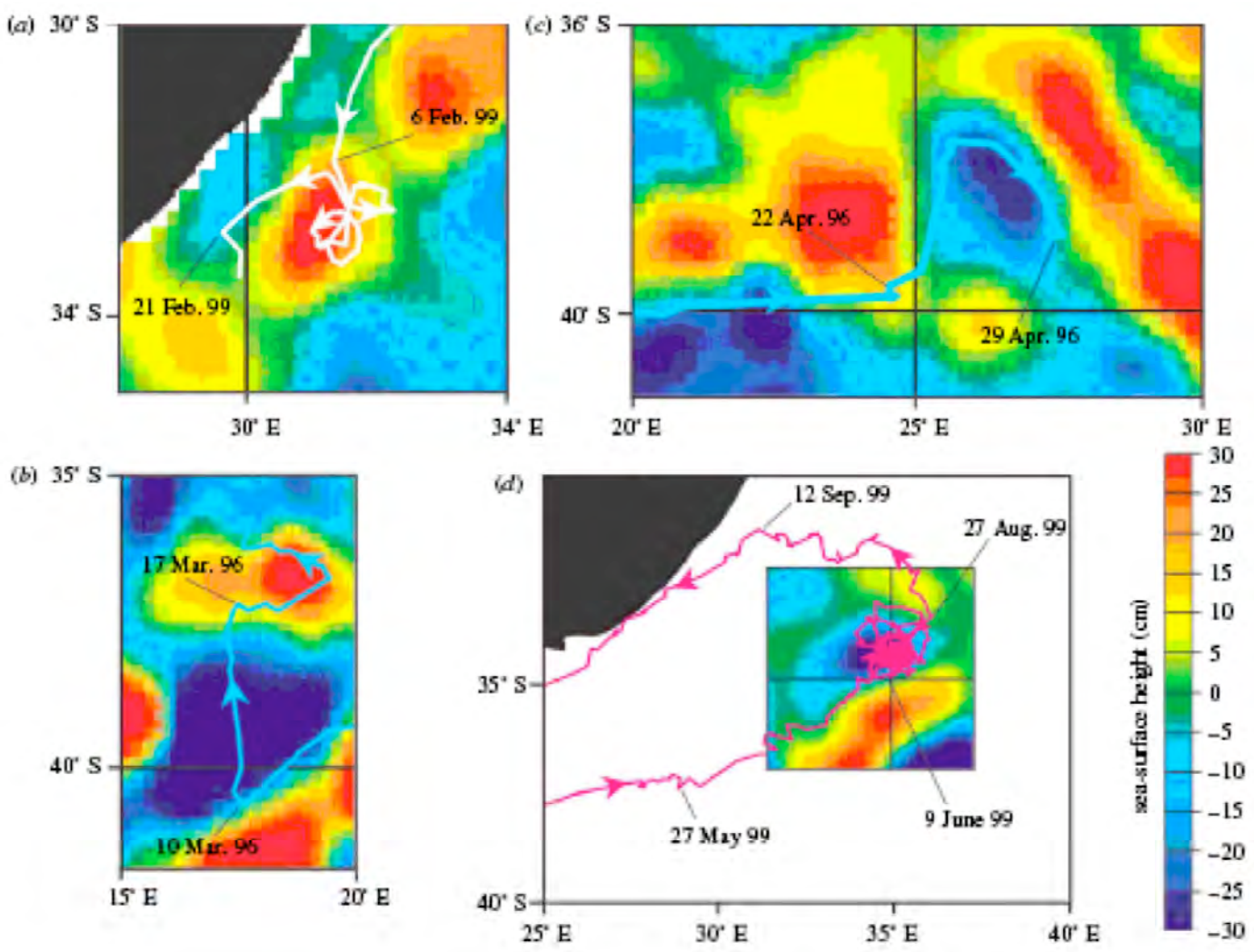
Later this turtle dove to 1250 meters depth southwest of Cape Verde islands, the deepest ever recorded for a reptile.



Leatherback Turtle Tracks in Eddies

Examples of looping segments of leatherback turtle tracks superimposed on SSHA images (Luschi et al., 2003).

d) Turtle remained in cyclone for three months.



Other Users/Applications

- Insurance Claims Adjustors
- Marine Architects
- Fisheries Managers
- Commercial Fishermen
- Search and Rescue
- Ocean Circulation Nowcasts/Forecasts/Hindcasts
- Forensic Oceanographers